National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

TPF Terrestrial Planet Finder

Emma X-Array Architecture for TPF-I / Darwin

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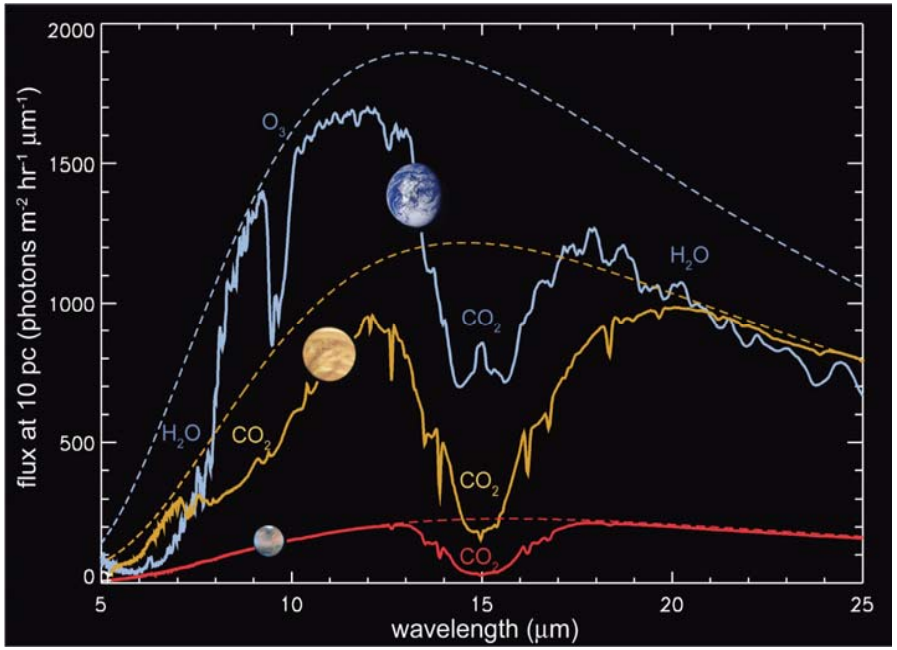
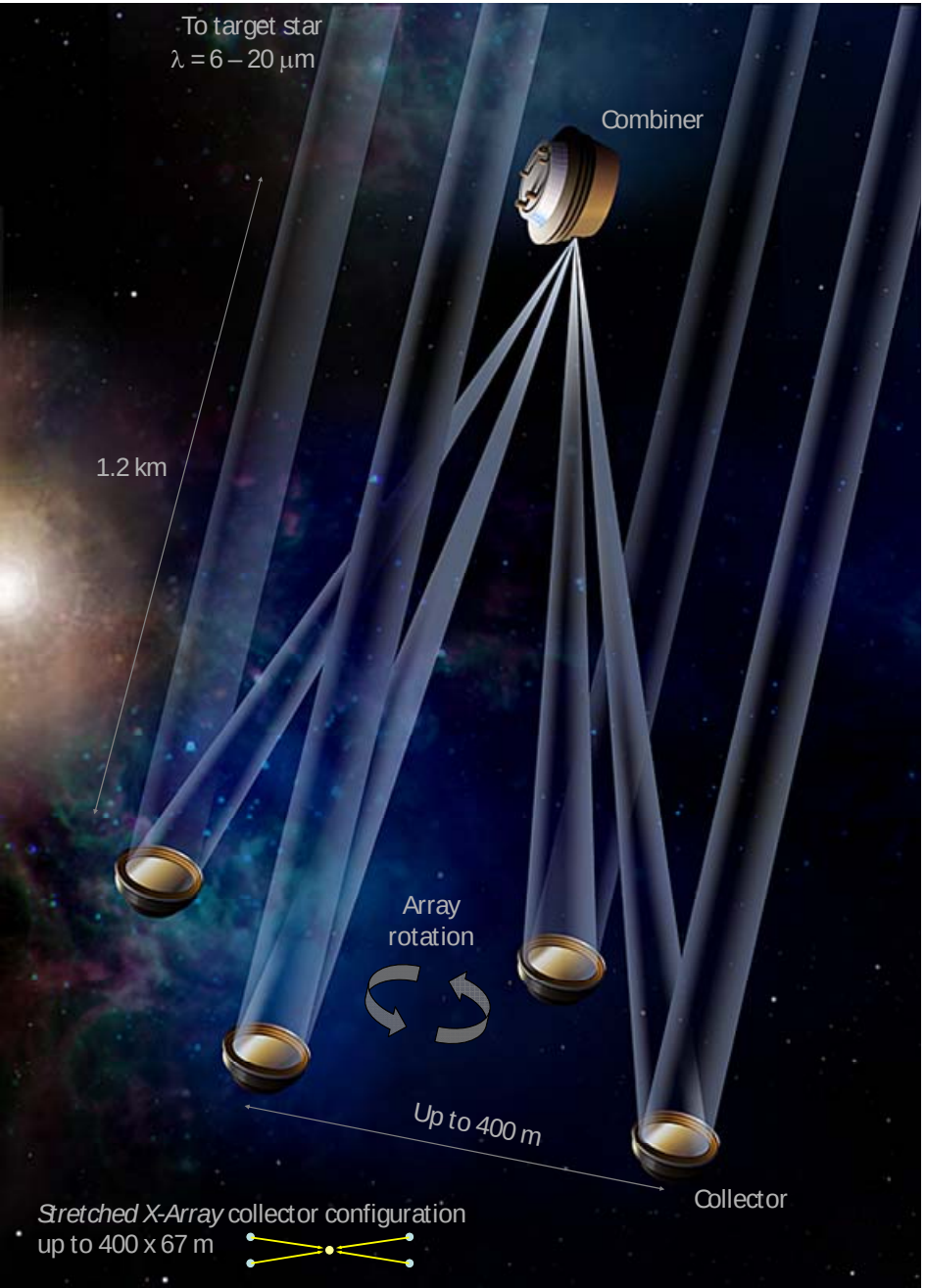
TPF-I / Darwin Key Features

- **Wavelengths**: Mid-Infrared 6 – 20 μm
- **Contrast**: Earth-Sun ~ 10^7 @ 10 μm
- **Biomarkers**: O_3, CO_2, CH_4, H_2O
- **Technique:** Nulling Interferometry
- **Implementation:** Formation Flying

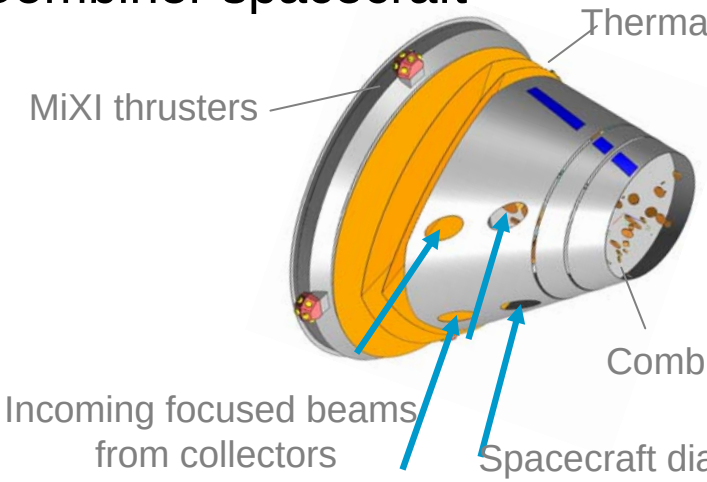


Selsis

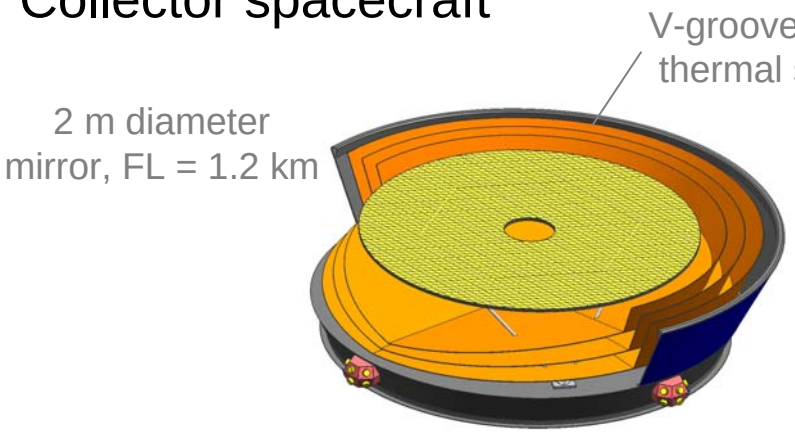
Emma X-Array Architecture



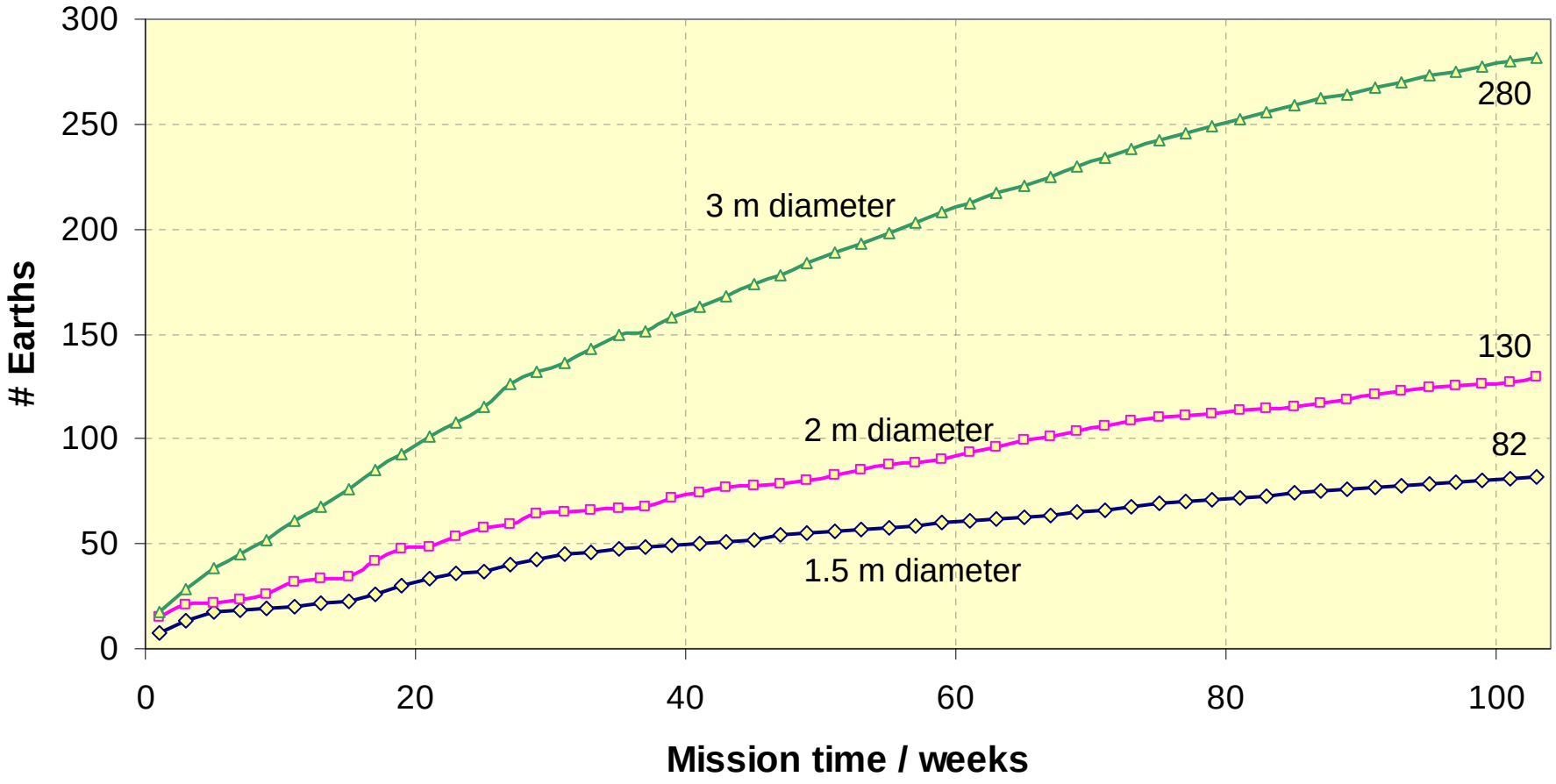
Combiner spacecraft



Collector spacecraft

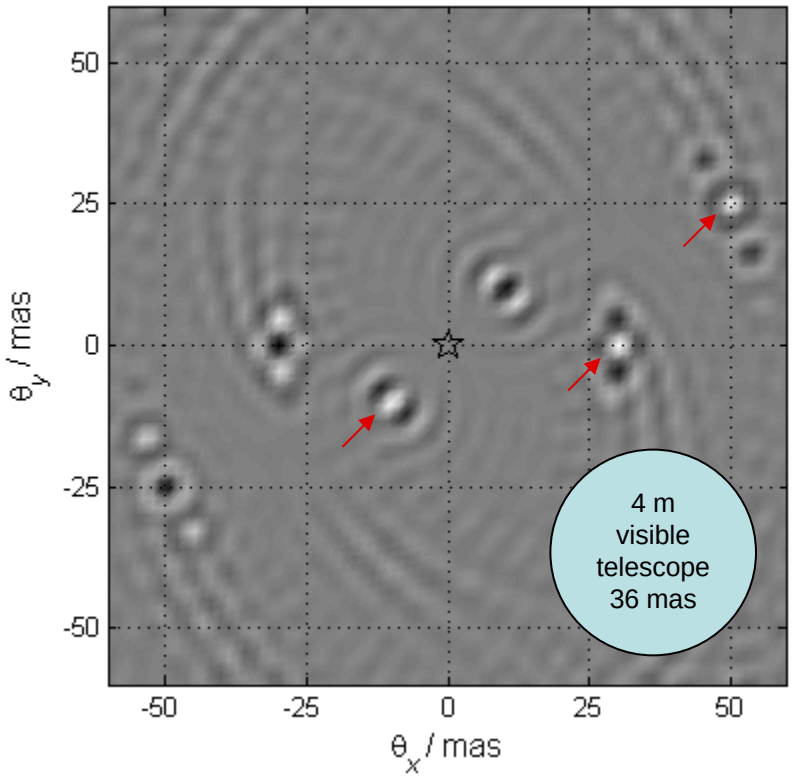


Earths found vs elapsed mission time



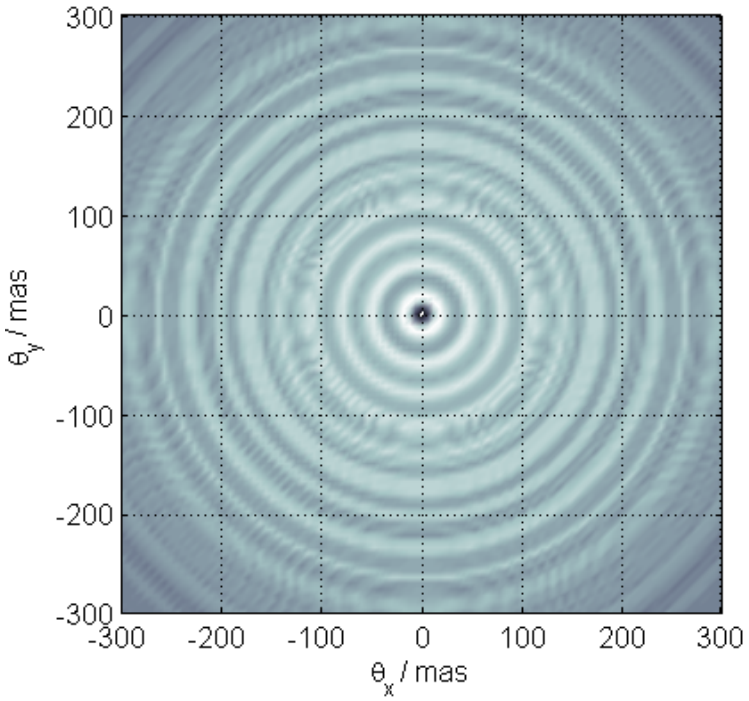
- 130 Earths after 2 years
- Assumes 1 Earth per star
- Only one visit per star in almost all cases

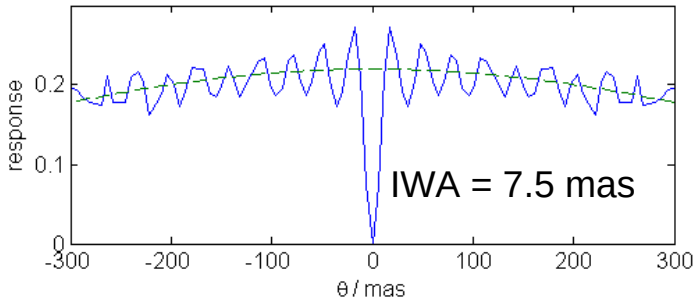
Imaging with 400 x 67 m array



- Dirty map, no deconvolution
- 3 planets
- FWHM ~ 2.4 mas
- Separates multiple planets

Sensitivity to planets

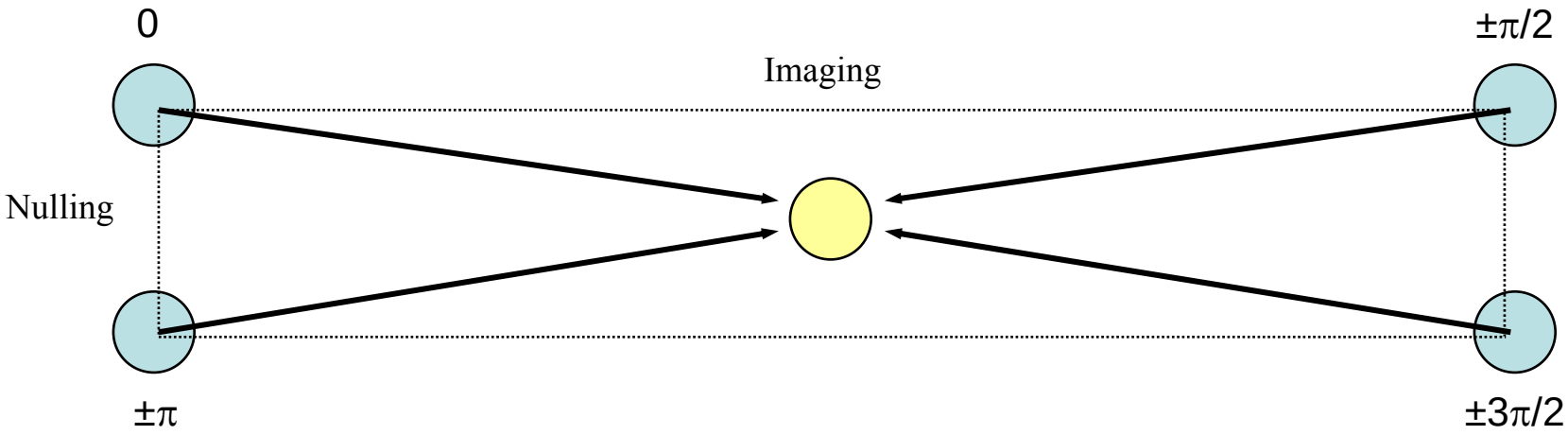




- Inner Working Angle down to 7.5 mas

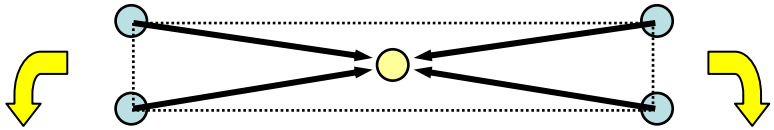
Back-up

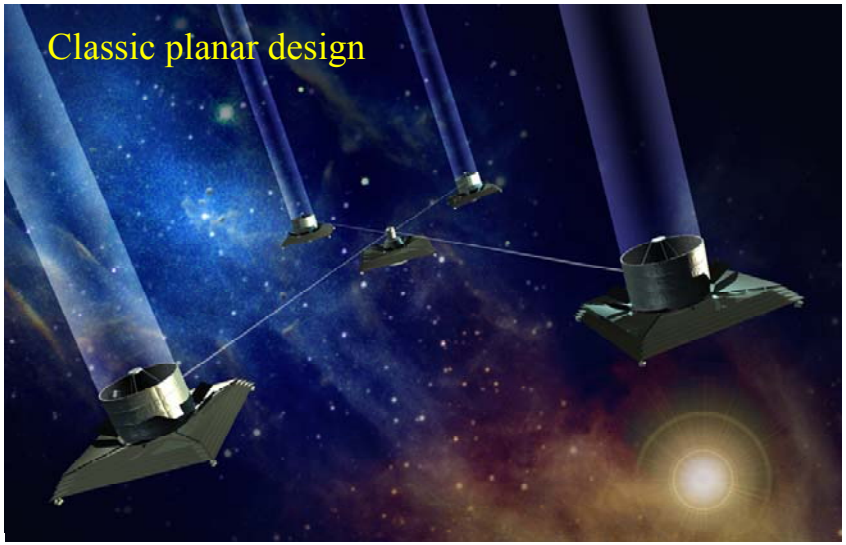
Stretched X-Array

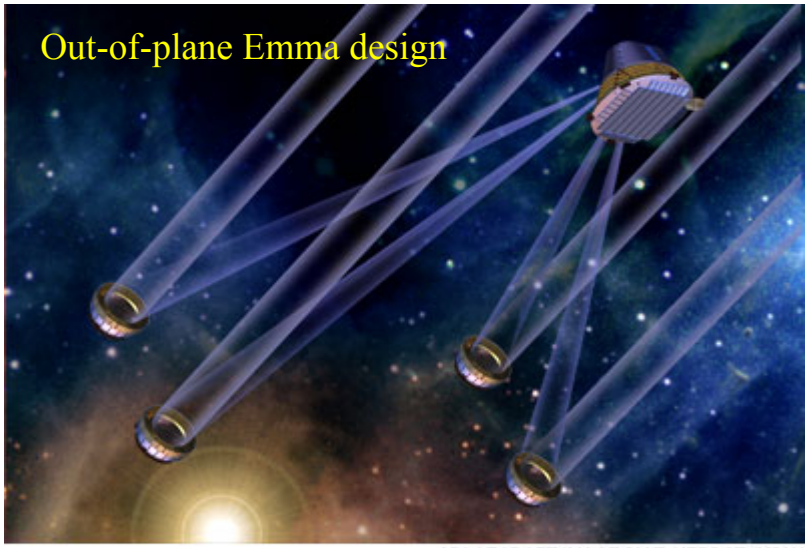


- ~ 6:1 aspect ratio
- Short nulling baselines, long imaging baselines
- Excellent angular resolution
- Can discriminate spectrally between planet signal and instrument ‘instability noise’

Implementation





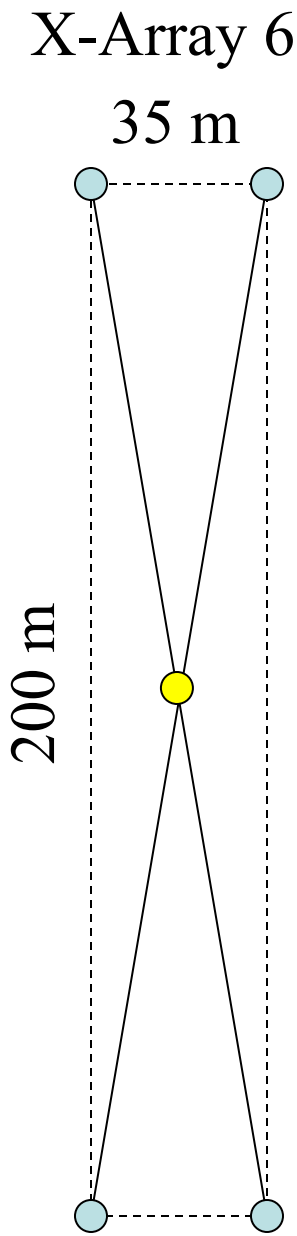


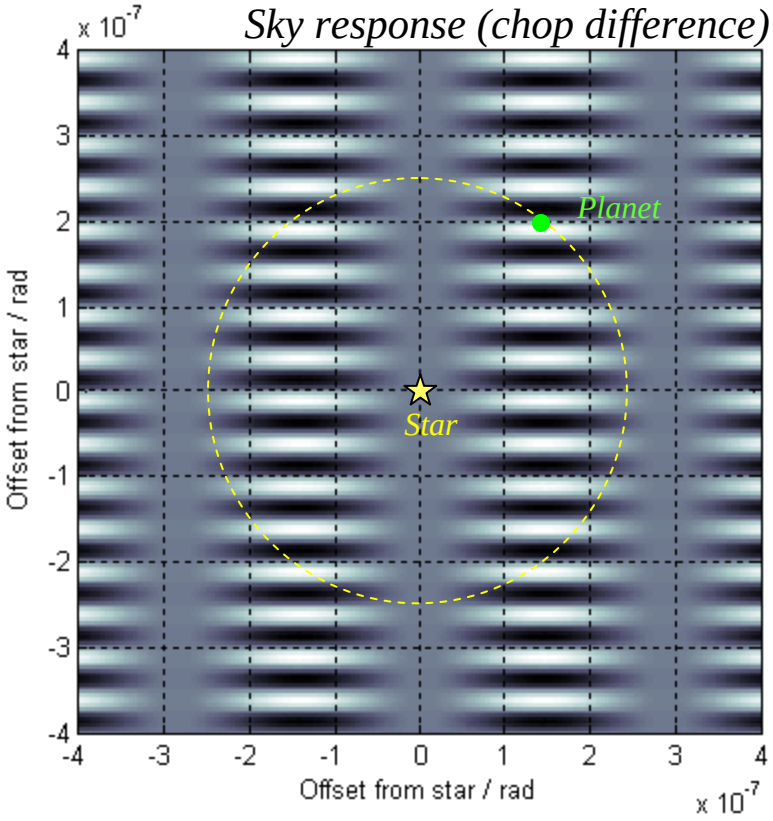
Performance discriminators

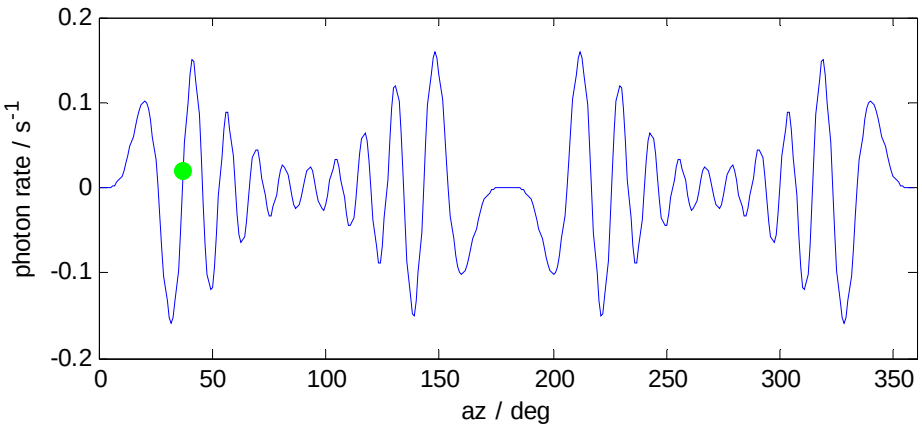
- Max. array size: 600 m
- Sky coverage: 71%

- Max. array size: 400 m
- Sky coverage: 99%

Response on the sky



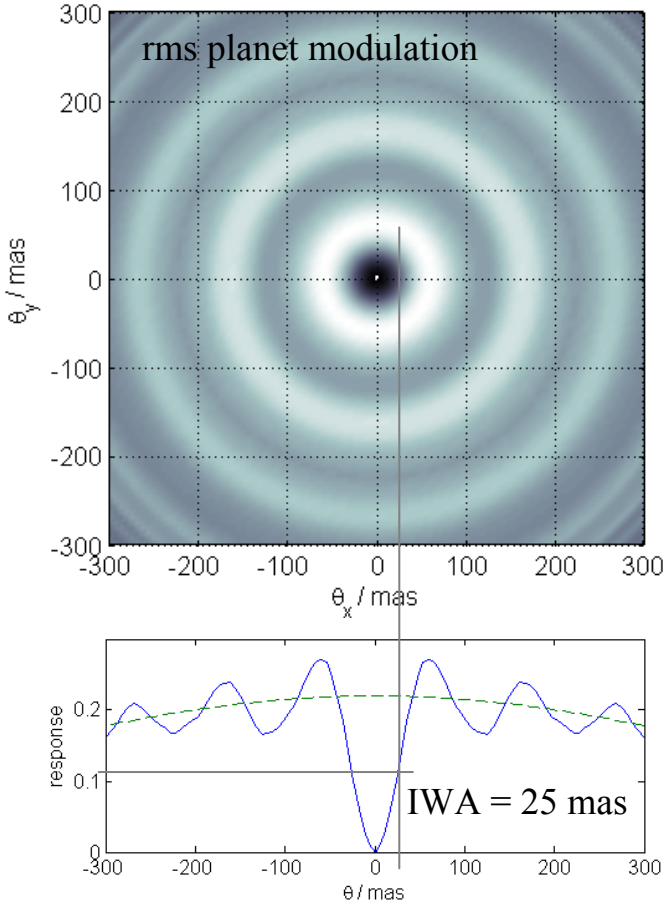




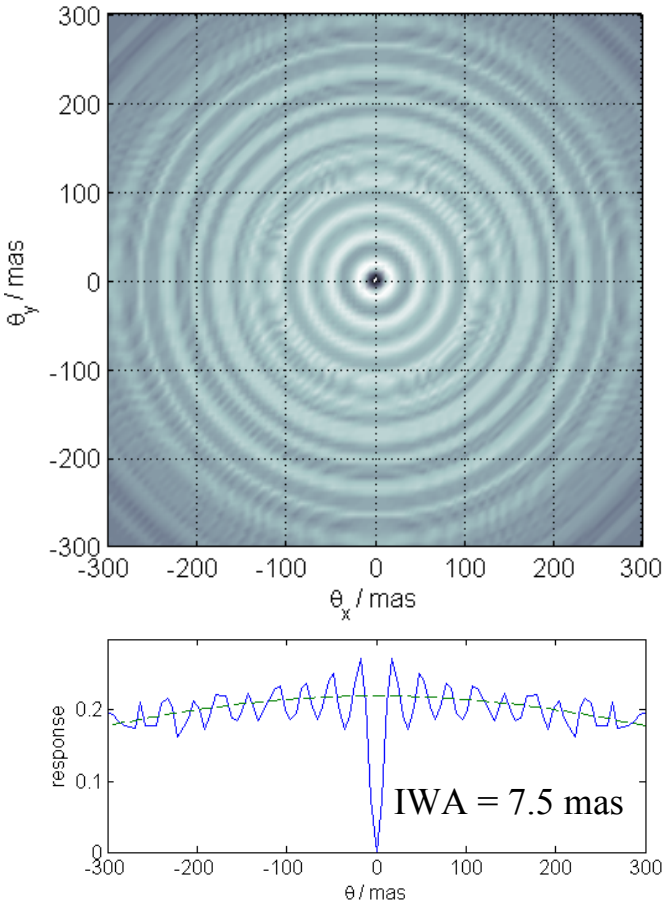
- λ = 10 μm
- Earth @ 50 mas = 2.5 x 10^{-7} rad

Inner Working Angle

120 x 20 m array



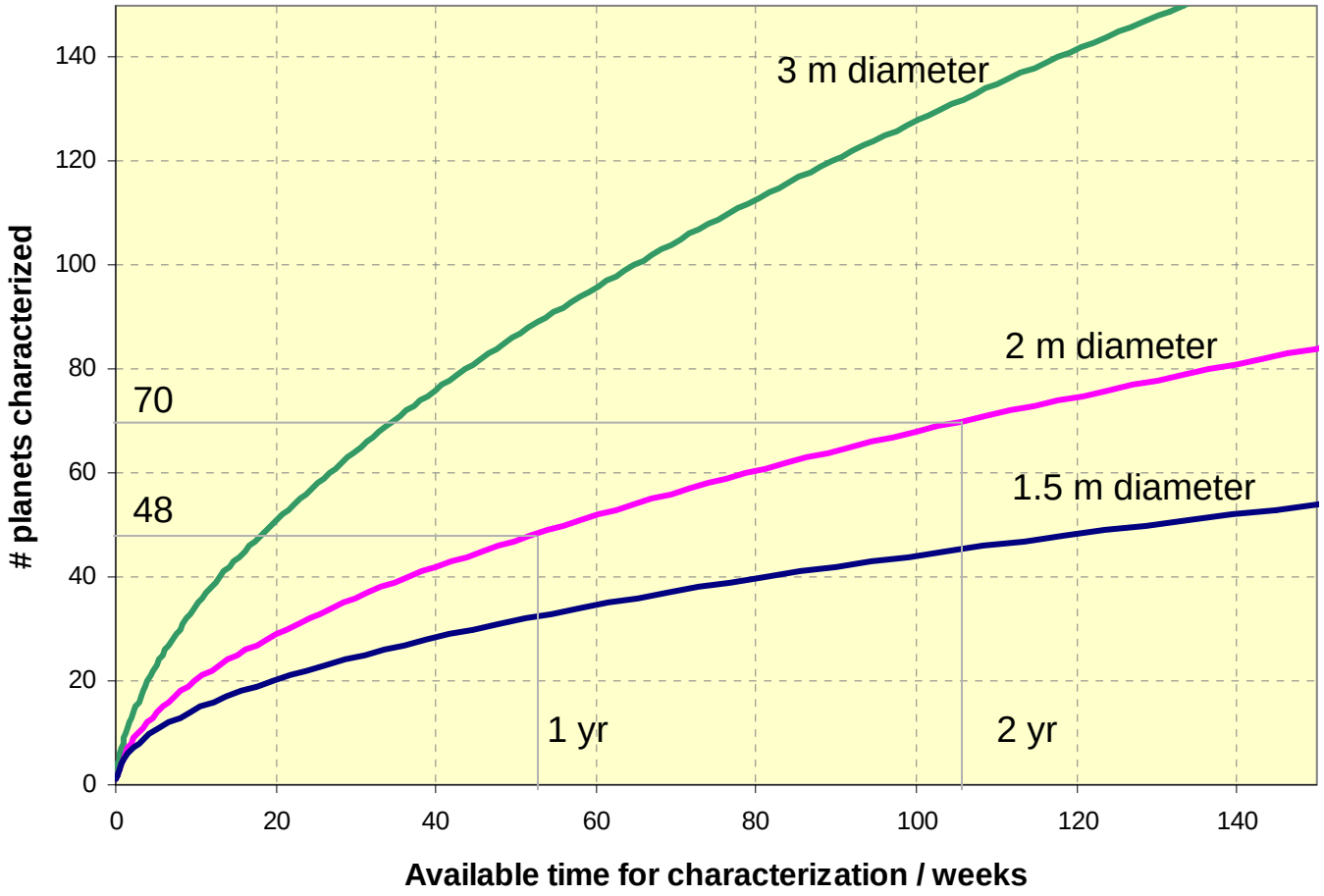
400 x 67 m array



Key observing parameters

Parameter	4-Telescope Chopped X-Array Emma Design
Collectors	Four spherical mirrors, diffraction limited at 2 μm operating at 50 K
Collector diameter	1.5, 2.0, 3.0 m
Array size	400 × 67 m to 120 × 20 m
Wavelength range	6–20 μm
Null depth	10^{-5} at 10 μm (not including stellar size leakage)
Exozodiacal emission	3 times our solar system, based on Kelsall model
Instrument throughput	10% (excludes ideal beam combiner losses)
Planet	Earth-sized 265 K black body
Retargeting time	6 hours
Integration efficiency	75%
SNR threshold	5

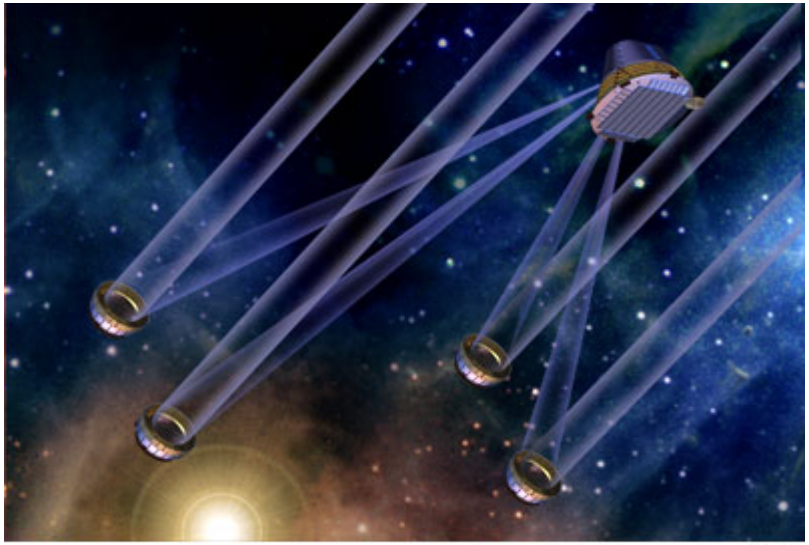
Spectroscopy



- SNR = 5 in 9.5 – 10 μm ozone channel
- 1 earth per star

Summary

- Emma X-Array design with 2 m collectors can detect ~ 130 Earths in 2 years
- Reduced array size is more than compensated by increased sky coverage
- Spectroscopy: ~ 50 nearest Earths in 1 year
- Excellent imaging with 2.4 mas angular resolution



SPACECRAFT IMAGE BY T. HERBST (MPIA)

Integration times for planet detection